

# Embedded MV-DC for Increased Penetration of Low Carbon Technologies

Freeing up latent grid capacity quickly and affordably

## Motivation

Electrification of heat and transport along with significant increases in distributed energy resources pose challenges for distribution network operators (DNOs) as they evolve into distribution system operators (DSOs). Issues may include capacity constraints, voltage excursions, lower supply security and reduced power quality. A method of addressing these matters whilst unlocking capacity is therefore required.

## Medium Voltage DC (MV-DC)?

MV-DC networks (operating in the range of 5-50 kV) represent a candidate technology to release capacity of existing assets without increasing system fault level.

MV-DC faces similar challenges to HVDC in the sense that semiconductor devices must withstand voltages that are not readily handled by single devices. However, a simple down scaling of HVDC is unlikely to yield the optimal solution as priorities for cost, volume, reliability and functionality are different.

MV-DC converters for grid applications reside between MV machine drives (used within wind turbines, traction, mining etc. generally between 2-14 kV rating) and HVDC operating at hundreds of kV. Although the power ratings of MV machine drives (typically 1-80 MVA) are similar to that which an MV-DC network solution will take, the voltage capability of such converters needs to be increased to reduce resistive losses.

Increasing power densities of power electronics and their reducing cost through market volume makes the prospect of reinforcing the conventional ac grid with dc elements more appealing.

## Power Flow Studies

This poster considers the case for the selective interconnection of grid supply points (GSP) and primary substations via fully controllable power electronic links upon an existing 33 kV distribution network (Fig. 2.). Power flows for the conventional network will be benchmarked before assessing the potential capacity release created by delivering energy from multiple substations via controllable interconnection. Substation loading is presented in Table 1.

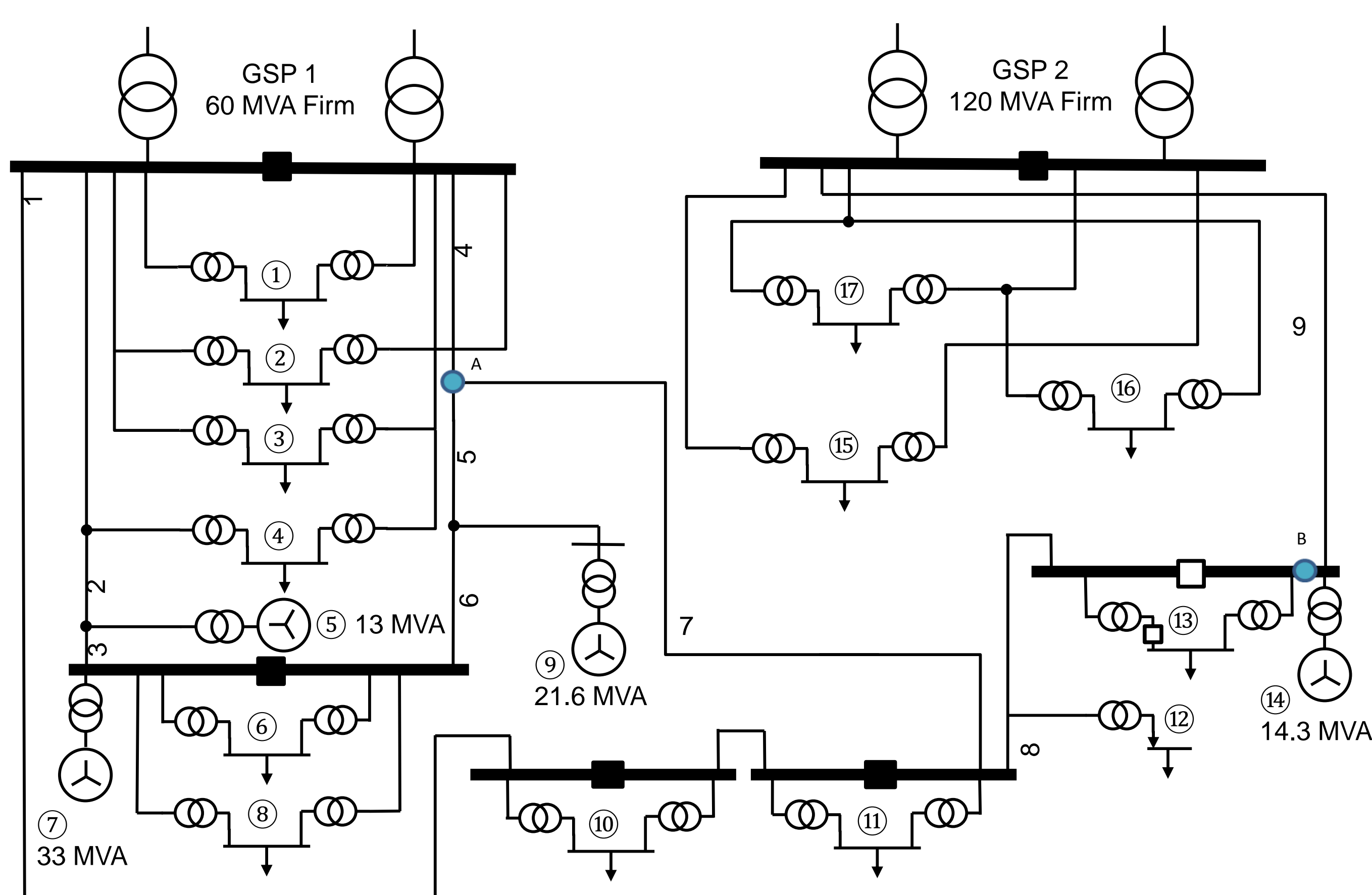


Fig 2. 'Real world' 33 kV network with significant levels of embedded generation.



Fig 1. Example of a 4 kV MV machine drive of 7 MW rating.

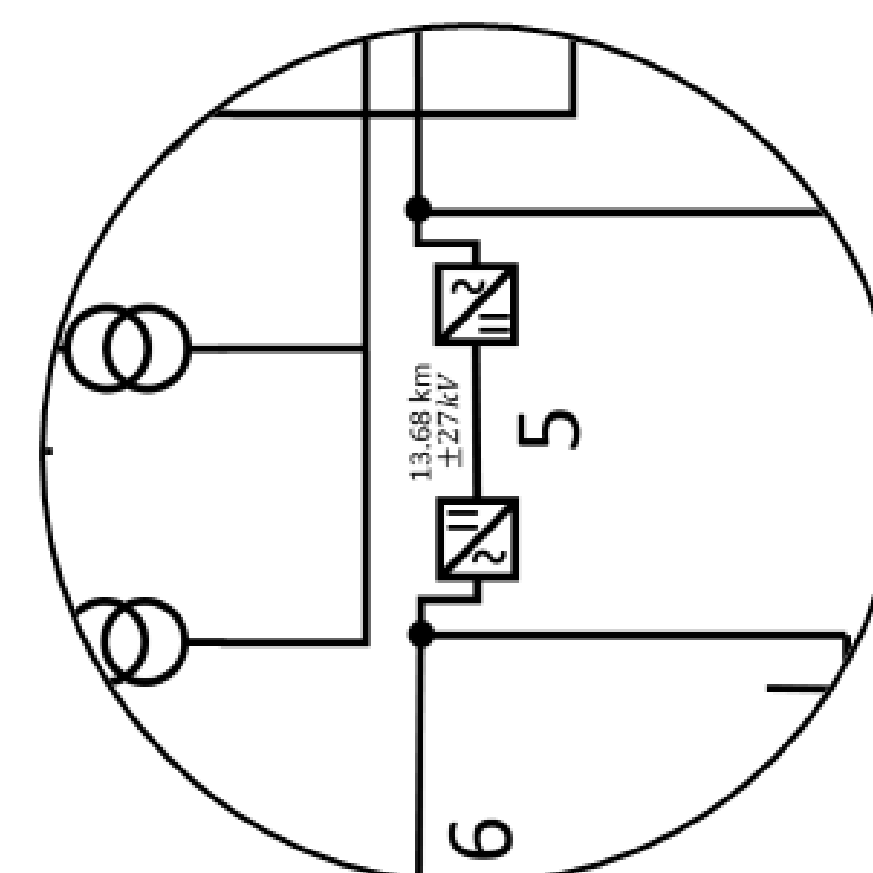


Fig. 3. Embedded MV-DC network link operating at  $\pm 27$  kV (repurposing of Line 5).

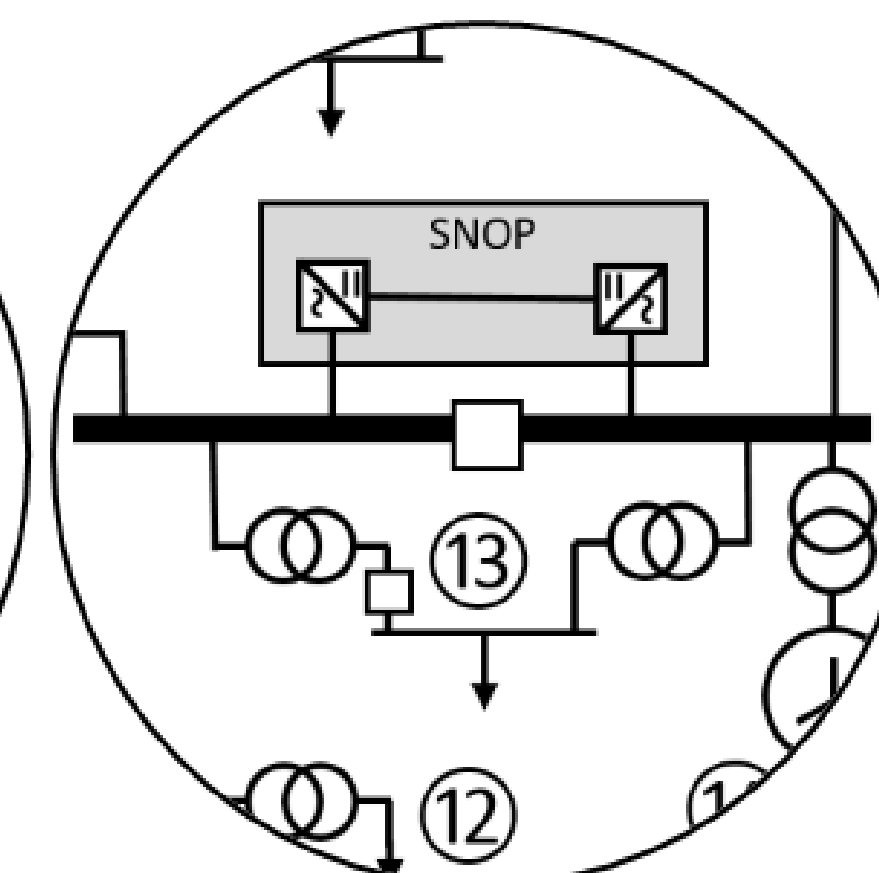


Fig. 4. Soft Normally Open Point (SNOP) connected across bus-coupler.

## Results

Table 2 shows line loading results. Red highlights line overloads. Yellow highlights lines loaded to >90% of thermal rating.

For maximum demand, the MV-DC link removes the immediate thermal overload but creates a new one elsewhere for minimum demand.

A SNOP (essentially a back to back converter) solves this problem even with the DNO predicted 34 MVA increase in generation at locations labelled A and B.

Table 2. Results from simulations under various loading scenarios and dc deployments

'DC+' = SNOP & MVDC line 5

'Base' = Network 'as is'

'Gen ↑' = Increase in DG of 19 MVA @ A and 15 MVA @ B

Line ID	Rating (MVA)	Length (km)	Loading (%)							
			Scenario		Base		DC Line 5		DC+	
			Demand		Max	Min	Max	Min	Max	Min
1	20.86	8.01	42	37	24	20	38	22	54	45
2	38.81	8.48	60	60	92	139	92	92	65	92
3	41.2	0.01	26	27	53	98	53	54	30	54
4	38.81	6.29	70	83	35	55	17	29	118	96
5	29.43	13.68	132	143	84	99	84	84	138	84
6	20.86	0.025	76	92	23	42	23	22	83	22
7	20.86	6.25	59	47	55	36	90	66	66	33
8	24.63	12.56	8	2	8	2	64	44	2	41
9	20.86	0.21	40	59	40	59	88	98	124	81

## Summary

Power flow analysis has highlighted that assets are stressed in places yet underutilised elsewhere, suggesting that rebalancing and rerouting of power is required.

It has been shown that dc technologies can be effective in alleviating problems – in this case, conversion of one line to dc and use of a SNOP has the potential to reduce congestion and to make better use of existing line assets.

The analysis has focussed on keeping within thermal limits and in that context results are encouraging. Power quality and security factors have not yet been addressed and neither have the relative costs compared to conventional ac reinforcement. An important consideration is the availability and maturity of the relevant dc technologies.

Practical implementation considerations (including protection, control and operational aspects) will be considered in the subsequent months.

## Acknowledgment

This work has been supported through the Engineering and Physical Sciences Research Council (EPSRC) Centre for Doctoral Training in Future Power Networks and Smart Grids (EP/L015471/1).